J Shoulder Elbow Surg (2018) ■■, ■■–■■

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ORIGINAL ARTICLE

Superior glenoid inclination and rotator cuff tears

Peter N. Chalmers, MD*, Lindsay Beck, BA, Erin Granger, MPH, Heath Henninger, PhD, Robert Z. Tashjian, MD

Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT, USA

Background: The objectives of this study were to determine whether glenoid inclination (1) could be measured accurately on magnetic resonance imaging (MRI) using computed tomography (CT) as a gold standard, (2) could be measured reliably on MRI, and (3) whether it differed between patients with rotator cuff tears and age-matched controls without evidence of rotator cuff tears or glenohumeral osteoarthritis.

Methods: In this comparative retrospective radiographic study, we measured glenoid inclination on T1 coronal MRI corrected into the plane of the scapula. We determined accuracy by comparison with CT and inter-rater reliability. We compared glenoid inclination between patients with full-thickness rotator cuff tears and patients aged >50 years without evidence of a rotator cuff tear or glenohumeral arthritis. An a priori power analysis determined adequate power to detect a 2° difference in glenoid inclination.

Results: (1) In a validation cohort of 37 patients with MRI and CT, the intraclass correlation coefficient was 0.877, with a mean difference of 0° (95% confidence interval, −1° to 1°). (2) For MRI inclination, the inter-rater intraclass correlation coefficient was 0.911. (3) Superior glenoid inclination was 2° higher (range, 1°-4°, $P < .001$) in the rotator cuff tear group of 192 patients than in the control cohort of 107 patients.

Conclusions: Glenoid inclination can be accurately and reliably measured on MRI. Although superior glenoid inclination is statistically greater in those with rotator cuff tears than in patients of similar age without rotator cuff tears or glenohumeral arthritis, the difference is likely below clinical significance.

Level of evidence: Level III; Diagnostic Study

Keywords: Rotator cuff tear; glenoid inclination; rotator cuff; etiology; critical shoulder angle; scapular morphology

The etiology of rotator cuff tears remains controversial.[4,27,29,39] Some have argued that rotator cuff tearing is a degenerative, age-related process[27,29] driven by hypoxia[42-45] and overuse.[26] Others have argued that scapular morphology plays a role.[1,4,8,15,22,28,39] Recently, multiple authors have shown the critical shoulder angle (CSA) to associate with rotator cuff tears.[3,13,18,23,34,37] The CSA is a combination measurement of the acromial index, which has been independently associated with rotator cuff tears,[3,37] and glenoid inclination, which has also been independently associated with rotator cuff tears.[13,23] Which of these factors is dominant remains unknown.

Superior glenoid inclination may alter the muscular vector of the deltoid and rotator cuff with respect to the articular surface. Superior glenoid inclination increases the shear component and decreases the compressive component of the rotator cuff and thus increases the mechanical load on the articular

This study was performed under University of Utah Institutional Review Board approval (Protocol # 71740).

*Reprint requests: Peter N. Chalmers, MD, Department of Orthopaedic Surgery, University of Utah, 590 Wakara Way, Salt Lake City, UT 84105, USA.

E-mail address: p.n.chalmers@gmail.com (P.N. Chalmers).

1058-2746/$ - see front matter © 2018 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
https://doi.org/10.1016/j.jse.2018.02.043

margin of the supraspinatus.[18,30,46] This increased load may contribute to rotator cuff tears.[6,13,23,36,40] However, other studies have not been able to demonstrate a clinically relevant relationship between CSA[5,11] or glenoid inclination[24] and rotator cuff tears.

Heterogeneity in the findings of the prior literature may have resulted from measurement bias and selection bias. Most of the prior studies were performed with 2-dimensional radiographs.[3,5,11,13,18,23,34,37] The CSA can only be reliably measured on a high-quality true anteroposterior radiograph,[41] and retrospective application of the strict criteria necessary to achieve reliable measurements can result in a substantial selection bias.[11]

In addition, glenoid inclination cannot be reliably measured on plain radiographs or even on computed tomography (CT) images unless these images are reoriented into the plane of the scapula.[9,20] However, inclination measurements have been demonstrated to be reliable on CT images reoriented into the plant of the scapula.[9] These measurements on CT have also been shown to be equivalent to gold standard automated 3-dimensional methods on CT.[9] However, no prior studies have determined whether magnetic resonance imaging (MRI) inclination measurements are equivalent to CT measurements or whether MRI inclination measurements are reliable. Furthermore, many prior studies did not have age-matched controls or had controls in whom the absence of rotator cuff tears and glenohumeral osteoarthritis was not confirmed radiographically.[3,5,11,13,18,23,34,37]

Thus, the objectives of this study were to determine whether we could (1) accurately measure glenoid inclination on MRI using CT as a gold standard and (2) reliably measure glenoid inclination on MRI, and (3) to determine whether glenoid inclination differs between patients with rotator cuff tears and age-matched controls without evidence of rotator cuff tears or glenohumeral osteoarthritis. We hypothesized that (1) we could accurately measure glenoid inclination on MRI using CT as a gold standard with an intrarater intraclass correlation coefficient (ICC) of >0.75 and an insignificant mean difference between measurements, (2) we could reliably measure glenoid inclination on MRI with an interrater ICC of >0.75, and (3) patients with rotator cuff tears would demonstrate greater superior glenoid inclination than age-matched controls that did not exhibit evidence of rotator cuff tears or glenohumeral osteoarthritis.

Materials and methods

To address our 3 objectives, we studied 3 patient groups. Informed consent was not required by our institutional review board for this retrospective radiographic study.

The first group of patients had an MRI and a CT scan and served as a validation population for inclination measurement accuracy. We conducted a review within our hospital system of all patients who had undergone an arthroscopic labral repair. We reviewed this list and only included patients who had undergone a CT scan and an MRI preoperatively within 6 months of each other. We excluded patients with evidence of osseous pathology or glenoid bone loss.

The second group of patients had rotator cuff tears and relevant medical imaging. We selected these patients from the clinical practice of the senior author (R.Z.T.) and included patients treated operatively and nonoperatively. Inclusion criteria included patients with full-thickness tears of the supraspinatus or infraspinatus on MRI aged between 30 and 80 years. Exclusion criteria included partial-thickness rotator cuff tears, significant glenohumeral arthritis, and prior surgery on the affected shoulder.[45] We screened each patient for inclusion by review of the MRI radiology report. An attending surgeon, fellowship trained in shoulder and elbow surgery (P.N.C.), then reviewed the images identified by this search. Only patients confirmed by the radiology report and the attending surgeon's review to have a full-thickness rotator cuff tear were included within the rotator cuff tear group.

The final patient group was a control cohort, aged older than 50, with relevant medical image data and no evidence of a rotator cuff tear or glenohumeral osteoarthritis. We searched our hospital system and created a list of all patients aged older than 50 who had undergone an MRI. A research associate (L.B.) then reviewed the radiology report for each MRI. An attending surgeon, fellowship trained in shoulder and elbow surgery (P.N.C.), then reviewed the images identified by this search. We only included patients confirmed by the radiology report and the attending surgeon's review to have no evidence of a partial-thickness or full-thickness rotator cuff tear or glenohumeral osteoarthritis within the control group. We excluded patients with glenohumeral osteoarthritis from the rotator cuff tear and control groups because glenohumeral osteoarthritis has also been demonstrated to associate with glenoid inclination.[5,36,40]

Data collection and radiographic measurement protocol

For each patient in the control and rotator cuff tear groups, we collected patient age at the time of the scan. For each patient in the rotator cuff tear group, we collected the following data: the tendons (subscapularis, supraspinatus, infraspinatus, teres minor) that were involved in the tear, the number of tendons involved in the tear, maximal tear width as measured on the sagittal T2 images, maximal tear retraction as measured on the coronal T2 images, and the Goutallier classification for each muscle[19] as measured on the most lateral T1 coronal image where the scapular spine and body remain confluent.

Glenoid inclination and glenoid version were measured for each patient in the control and rotator cuff tear groups as described previously.[9] All measurements were performed in an OsiriX viewer (Pixmeo Sarl, Bern, Switzerland). Inclination measurements were made on T1 coronal images to provide the best osseous detail.

First, these coronal images were reoriented into the plane of the scapula. The plane of the scapula is defined by (1) the inferior pole, (2) the medial border on an axial slice at the middle of the glenoid, and (3) the center of the glenoid.[7] On the reoriented coronal image at the center of the glenoid, we measured the distance from the medial aspect of the image to the lateral aspect of the glenoid. We only included individuals with a minimum of 8 cm of scapular width imaged because lesser widths have been shown to be associated with significant measurement alterations.[10] We considered individuals without a T1 coronal image or without 8 cm of scapular width imaged to have inadequate quality scans.